Results from Trial Testing of Geofencing Functionality For NT Transit and Smart Parking

California PATH Program
March 31, 2010

The purpose of this memo is to provide a summary description and trail testing results of "Geo-Fencing" (G-F) developed specifically for the NT transit and smart parking applications under the SafeTrip-21 Program to the US Department Transportation and California Department of Transportation for their approval of the planned field operational tests.

1. NT Transit and Smart Parking with Geofencing

The core of the re-scoping is to add Geo-Fencing functionality to the NT transit and smart parking applications to enable the detection of driving by the applications and therefore to avoid usage of the application by drivers as much as possible. In this context geo-fencing includes identification of location and traveling mode of the cell-phone use.

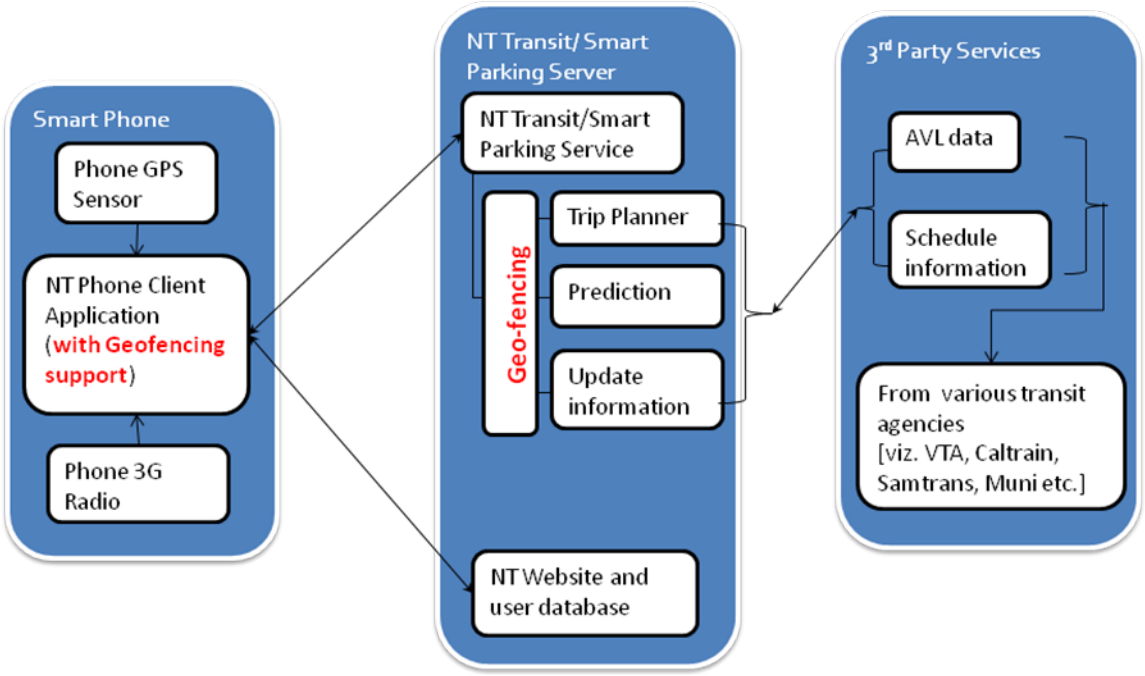

Figure 1 Geo-fenced NT Transit / Smart Parking System

2. Design and Implementation of the Geo-fencing

2.1 Server-Client Implementation of Geo-Fencing

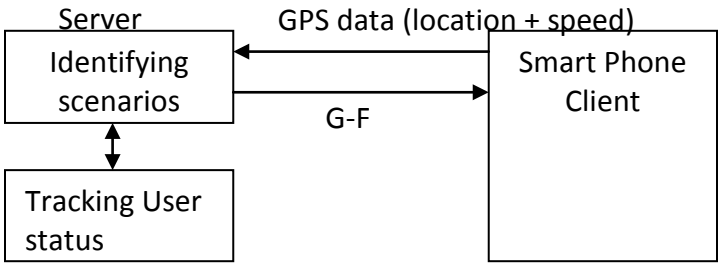

Figure 2 A Server-Client Implementation of G-F

The G-F design is based on a server side, location-based service which identifies "scenarios" of the user using their GPS traces and their origin and destination (if there are any available). The smart phone client must have GPS enabled. When the NT transit /smart parking program is initiated, GPS data from the client (including location and speed) will be sent to the server continuously unless the user is detected to be onboard a bus therefore cell phone GPS is turned off in order to request information update.

The implementation of the G-F is done with server-side logic and a thin client design. Therefore, different phone operating systems (OS) on should not have an impact on the performance of the G-F. Additionally, a phone with better GPS accuracy could result in better G-F performance. However the G-F is designed to rely on only current, normal phone GPS accuracies.

Also, G-F only works when the application is activated; no transit / smart parking information will be displayed by the application, nor will any input be allowed by the app, when it detects that the user is (more likely) driving; and finally, the system does not take into account of the difference of bicyclists' behavior rendering G-F ineffective for bicyclists.

2.2 Scenario Identification for G-F

The design allows the system to identify the following scenarios:

Scenarios		Identifiable	Note
Pre-trip	Making a trip plan while driving *vs* Making a trip plan while not driving	Yes	System uses (1) speed from the GPS data to enable G-F System; (2) Distance of the user from road and bus stop is also taken into consideration while making a decision.
	Making a trip plan while not driving and near a road and bus stop *vs* Making a trip plan while not driving and not near a road and bus stop	Yes	
	Making a trip plan while riding a bus/train * *vs* Making a trip plan	No	* In this case system has no prior knowledge of status to distinguish

	while driving		between the two cases and blocks launching of trip planner
En route	User is walking towards train / bus station *vs* User is driving towards train / bus station	Yes ✔	System uses the (1) saves a state machine tracking the location and speed history of the user; (2) matches the location of the user to the buses / trains, to differentiate the mode. Trying to mimic the behavior of buses by a car (e.g. stops at a bus stop, or driving on the route following a bus) can cause false fencing.
	User waiting at the bus stop *vs* Pass the bus / train stop while driving	Yes ✔	
	User is riding the bus / train *vs* User is driving along the bus route	Yes (with constraints)	

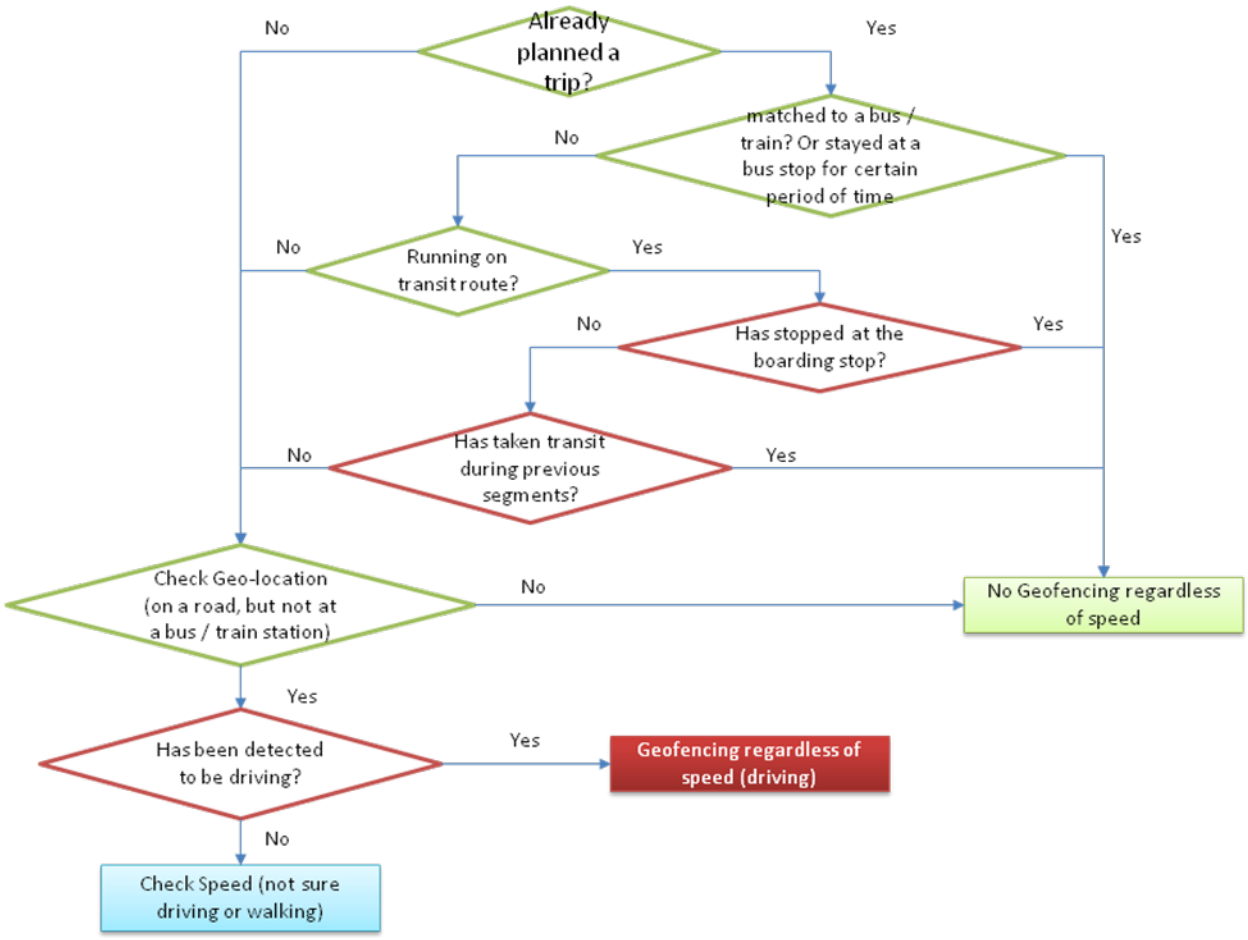

Figure 3 Server Side Scenario Identification for G-F ('Check speed' threshold=3mph, speed higher than which triggers G-F)

Due to the limitations of the GPS accuracy and the potential complicated nature of travel, identification of the traveler behavior is subject to errors. Different types of errors lead to

different consequences. The design of the system therefore aims at minimizing missed detection during driving while keeping the false-blocking rate low.

3 .Testing and Evaluation of G-F

The performance of the G-F functionality is measured by the successful detection rate of the user-driving, versus the false alarms while user is not driving, given the listed scenarios.

While developing G-F, we identify additional factors that would compromise the usability and the rate of missed detection of usage by drivers. These factors include more than the rate; they include the characteristics of each occurrence of what may be missing.

3.1 System testing of G-F

System testing at the field was carried out at March 15th and March 24th, 2010. The testing was conducted by two testers from PATH, traveling the following route:

- Caltrain, then
- VTA 522: Palo Alto, California Ave, Arastradero Ave, Showers Ave, Castro Ave.

A total of 20 trips were made, including 16 en-route trips (where ten trips involved driving and six trips with transit and walking) and 4 pre-trip test cases.

En route	Test cases	G-F result
Walking toward the bus / train stop then take transit + riding the bus / train	03/15: 11:30 am, walking toward VTA 522 California ECR stop, the take bus to Showers ECR,	did not block ✔
	03/15 12pm from VTA Showers ECR to California ECR.	did not block ✔
	03/15 1:20 pm from VTA 522 California ECR to Palo Alto	did not block ✔
	03/15 2:20 pm from Caltrain California Ave to Caltrain Palo Alto	did not block ✔
	03/24 1:40pm VTA California ECR to Arastradero ECR	did not block ✔
	03/24 1:55pm VTA Arastradero ECR to Showers ECR	did not block ✔
	03/24 2:10pm VTA Showers ECR to California ECR	did not block ✔

	Driving toward bus / train stop then wait at bus / train stop	03/24 2:20pm drove to Caltrain California Ave, planner trip from California Ave to San Francisco	Blocked while driving, and did not block after parked at the parking lot ✔
		03/15 1:50 pm drove to Caltrain California Ave station, planner trip from California Ave to San Francisco	Same as above ✔
		03/24 2:46pm drove to Caltrain California Ave, planner trip from California Ave to Mountain View	Same as above ✔
		03/24 2:50pm Drove from California Ave to Palo Alto train station, parked at the train station. planner trip from Palo Alto to San Francisco	Same as above ✔
		03/24 3:02 pm Drove from Palo Alto to California ECR, parked at the street parking. Planned trip from California ECR to Showers ECR VTA 522	Same as above ✔
	Driving toward bus / train stop + driving on the bus route	03/24 3:22 pm Drove from California ECR to Arastradero ECR, drove on bus route then made a U-turn and drive back. Planned trip from Arastradero ECR to Showers ECR VTA 522	Blocked while driving ✔
		03/15 2:40 pm Drove from California ECR to Showers ECR, drove on toward the bus stop then drove on the bus route. Planned trip from California ECR to Showers ECR 522	Blocked while driving ✔
		03/24 3:32 pm Drove from Arastradero ECR to Palo Alto, drove on toward the bus stop then drove on the bus route. Planned trip from California ECR to Palo Alto VTA 522	Blocked while driving ✔
		03/24 3:45 pm Drove from Palo Alto to California Ave, drove on the bus route. Planned trip from California ECR to Palo Alto VTA 522 A bus was following our car.	Blocked at first. Then started showing information ⚠
Pre trip			
	Making a trip plan some distance from a road and bus stop, while not driving	03/24 11:30 am Making a trip plan from Bldg. 180 at RFS	Did not block ✔

	and		
	Making a trip plan near a road and bus stop, while not driving	03/24 12:40 pm Making a trip plan from a stationary position at Central Ave off 580	Did not block 
	Making a trip plan while driving	03/24 12:45 pm Making a trip plan while driving from Central Ave off 580 to ECR in South Bay	Blocked 
	Making a trip plan while riding a bus/train	03/24 2:15pm VTA Showers ECR to California ECR	Blocked 

Total **En route:**
6 walking + transit cases: all ok,
10 involved driving, 9 were successful. 1 failed because a bus for the planned route was following the car.
Pre-trip:
4 different scenarios, 3 were successful, 1 failed as the system did not have enough information if the user was driving or taking transit.

3.2 Data Archiving for Evaluation

With our impending FOT, the raw data (ground truth of the scenario of each test and the output of the new system with geo-fencing) will be recorded. Statistics of the error detection rate (two types of errors) will also be calculated. PATH will be responsible for data archiving and processing. Both the raw data and the processed results will be provided to the independent evaluator upon request.

G-F scenario	Performance	Data	Hypothesis
Pre-trip	The statistics of rate of errors of the G-F detection User perception of the G-F success rate and the usability of the	User survey of a small group of testers from PATH.	G-F could effectively prevent (discourage) the usage of the application while driving.

	application.		
En route	The statistics of rate of errors of the G-F detection User perception of the G-success rate and the usability of the application.	Ground truth data (whether it is driving or not) and the G-F output will be collected by a passenger in the car, or the bus rider.	